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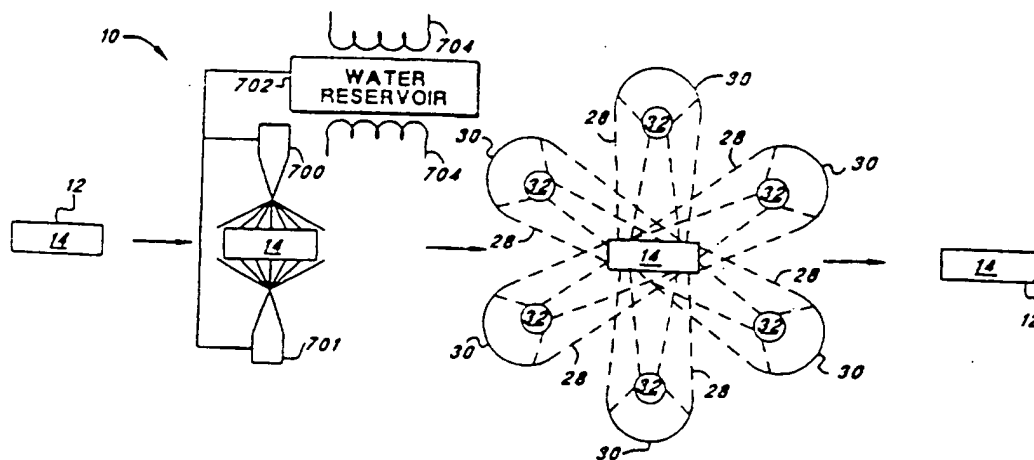
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(54) Title: PULSED LIGHT TREATMENT OF FOOD PRODUCTS AND PACKAGING MATERIALS



(57) Abstract

An improved method and apparatus for deactivating organisms on the surface of a perishable food product, or on the surface of a packaging material includes, in one embodiment, a heating device (700, 704) for heating a surface of the food product or packaging material to a prescribed temperature, and a flashlamp system (30) for illuminating the surface of the food product or packaging material with light (28) having frequencies within a prescribed frequency range. At least a portion of the light with which the food product or packaging material is illuminated deactivates organisms substantially at the surface of the food product or packaging material. In another embodiment, the method includes applying a chemical agent to the surface of the food product or packaging material, instead of or in addition to the heating of the food product or packaging material. A further embodiment employs modified atmosphere packaging in combination with illumination of a food product contained therein.

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## PULSED LIGHT TREATMENT OF FOOD PRODUCTS AND PACKAGING MATERIALS

5 Background of the Invention

The present invention relates to the preservation of a food product, and more particularly to the prolongation of the shelf-life of such food product. Even more particularly, the present invention relates to improved systems and methods for the deactivation of organisms on a surface of the food product.

Fresh meats, fruits, vegetables, and other food products, for example beef carcasses, accumulate organisms, which as used herein includes bacteria, viruses, and fungi, from the air, ground, water and other sources with which they come into contact. These organisms, through various known mechanisms, cause the perishable food products to spoil, thereby significantly limiting the shelf-life of the food products. (Shelf-life is the period of time during which the perishable food product can be stored refrigerated or unrefrigerated, and remain edible and free from noticeable or harmful degradation or contamination by organisms.) As a result, methods and apparatuses suitable for deactivating, i.e., killing or sterilizing, such organisms and thereby extending the shelf-life of perishable foods, such as meats and other edible food products, are desirable.

The photobiological effects of light, including infrared light (780 nm to 2600 nm; i.e.,  $3.9 \times 10^{14}$  Hz to  $1.2 \times 10^{14}$  Hz), visible light (380 to 780 nm; i.e.,  $7.9 \times 10^{14}$  Hz to  $3.9 \times 10^{14}$  Hz), near ultraviolet light (300 to 380 nm; i.e.,  $1.0 \times 10^{15}$  Hz to  $7.9 \times 10^{14}$  Hz) and far ultraviolet light (170 to 300 nm; i.e.,  $1.8 \times 10^{15}$  Hz to  $1.0 \times 10^{15}$  Hz), have been studied, and efforts have been made to employ light to deactivate organisms on food products and packaging materials for food products. See, e.g., U.S. Patent No.

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4,871,559, issued to Dunn et al. (the '559 patent),  
incorporated herein by reference. Systems and methods  
employing the photobiological effects of light to  
deactivate, i.e., kill or sterilize, substantially all  
5 (i.e., more than 50%, e.g., 90%, deactivation rate) of  
the organisms on the surface of the food product and/or  
packaging material have proven to be effective in  
extending the shelf-life of perishable food products.

One improvement to systems that utilize the  
10 photobiological effects of light to effect deactivation  
of organisms on food products or food packaging materials  
is to treat the food product or food packaging material  
with an absorption enhancing agent prior to the  
illumination of the food product or packaging material.  
15 See e.g., the '559 patent. Absorption enhancing agents  
have a high optical absorption coefficient at at least a  
portion of the spectral wavelengths with which the food  
product or packaging material is to be illuminated.

Another improvement to systems that utilize the  
20 photobiological effects of light to effect deactivation  
of organisms on food products is to subject the food  
product to a high pressure water wash prior to the  
illumination of the food product. See e.g., the '559  
patent. The high pressure water wash physically removes  
25 some organisms from the surface of the food product prior  
to the illumination.

While these improvements to systems and methods  
that employ the photobiological effects of light to  
effect a prescribed level of deactivation of organisms on  
30 food products or food packaging materials are  
advantageous, further improvements in the deactivation  
rate, reduction of the time required to achieve a desired  
deactivation rate, and/or reduction of the energy needed  
to effect deactivation or kill are needed and highly  
35 desirable.

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The present invention advantageously improves upon heretofore known systems and methods employing the photobiological effects of light to deactivate organisms.

5 Summary of the Invention

The present invention advantageously addresses the needs above as well as other needs by providing an improved system and method for deactivating organisms on a surface of a food product or on the surface of a  
10 packaging material. The invention advantageously employs heretofore unknown synergies that exist between pulsed light treatment, and thermal, chemical or modified atmosphere packaging treatments.

In one embodiment, the invention can be  
15 characterized as an improved method for deactivating organisms on the surface of a perishable food product, or on the surface of a packaging material. Such method includes heating a surface of the food product, packaging material or atmosphere adjacent to such food product or  
20 packaging material to a prescribed temperature, and illuminating the surface of the food product, packaging material with light having frequencies within a prescribed frequency range. At least a portion of the light with which the food product or packaging material  
25 is illuminated deactivates organisms substantially at the surface of the food product or packaging material.

Such embodiment can also be characterized as a system for carrying out the above method. The system includes heating means for heating a surface of the food  
30 product, packaging material or adjacent atmosphere to a prescribed temperature, and illuminating means for illuminating the surface of the food product or packaging material with light. As above, the light has frequencies within a prescribed frequency range, and at least a  
35 portion of the light deactivates organisms substantially at the surface of the food product or packaging material.

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In another embodiment, the invention can be characterized as a method for deactivating organisms substantially at a surface of a food product or packaging material including: applying a chemical agent to the  
5 surface of the food product or packaging material, and illuminating the surface of the food product or packaging material with light having frequencies within a prescribed frequency range. At least a portion of the light deactivates organisms substantially at the surface  
10 of the packaging material.

Such embodiment can also be characterized as a system for preserving a perishable food product or for deactivating organisms at a surface of a packaging material. The system includes: applying means for  
15 applying a chemical agent to a surface of the food product or packaging material, and illuminating means for illuminating the surface of the food product or packaging material with light. The light has frequencies within a prescribed frequency range, and at least a portion of the  
20 light deactivates organisms substantially at the surface of the food product or packaging material.

A further embodiment of the invention may be characterized as a method for preserving a perishable food product including: sealing the food product within a  
25 package designed to contain a modified atmosphere, and illuminating the package with light having frequencies within a prescribed frequency range. At least a portion of the light passes through the package and deactivates organisms substantially at the surface of the food  
30 product.

Such further embodiment may also be characterized as a system for preserving a perishable food product including: packaging means for sealing the food product within a package designed to contain a  
35 modified atmosphere, and illuminating means for illuminating the package with light having frequencies

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within a prescribed frequency range. As above, at least a portion of the light passes through the package and deactivates organisms substantially at the surface of the food product

5 Even further embodiments of the invention employ a combination of one or more of the above-described systems and methods, i.e., a combination of one or more of the above-mentioned synergies, in order to achieve improved deactivation of organisms at or near the  
10 surface of a food product or packaging material.

It is therefore a feature of the invention to deactivate organisms substantially at a surface of a food product or food packaging material.

15 It is another feature of the invention to provide an improved pulsed light treatment system and method that employs thermal, chemical and/or modified atmosphere packaging synergy.

#### Brief Description of the Drawings

20 The above and other aspects, features and advantages of the present invention will be more apparent from the following more particular description thereof, presented in conjunction with the following drawings wherein:

25 FIG. 1 is a schematic diagram of a pulsed light treatment system employing chemical agent synergy to achieve an improved organism deactivation rate substantially at a surface of a food product;

FIG. 1A is a graph showing results of a  
30 demonstration test of the pulsed light treatment system of FIG. 1 using *Escherichia coli* treated with acetic acid and two flashes of intense, short duration, broad spectrum, polychromatic light;

35 FIG. 1B is a graph showing results of another demonstration test of the pulsed light treatment system of FIG. 1 using *Escherichia coli* treated with acetic acid

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and three flashes of intense, short duration, broad spectrum, polychromatic light;

FIG. 1C is a graph showing results of a demonstration test of the pulsed light treatment system of FIG. 1 using Salmonella typhimurium treated with acetic acid and two flashes of intense, short duration, broad spectrum, polychromatic light;

FIG. 2 is a schematic diagram of a pulsed light treatment system employing chemical agent synergy to achieve an improved organism deactivation rate substantially at a surface of a packaging material;

FIG. 3 is a detailed perspective view of a first type of aseptic packaging apparatus that includes an embodiment of the pulsed light treatment system of FIG. 2 employing chemical agent synergy;

FIG. 4 is a partial perspective view of the aseptic packaging apparatus of FIG. 3 showing a high intensity incoherent pulsed light filling and sterilization assembly;

FIG. 5 is a detailed perspective view of a second type of aseptic packaging apparatus that includes another embodiment of the pulsed light treatment system of FIG. 2 employing chemical synergy;

FIG. 6 is a detailed perspective view of a third type of aseptic packaging apparatus that includes another embodiment of the pulsed light treatment system of FIG. 2 employing chemical synergy;

FIG. 7 is a schematic diagram of a pulsed light treatment system employing thermal synergy to achieve an improved organism deactivation rate substantially at a surface of a food product;

FIG. 8 is a schematic diagram of a pulsed light treatment system employing thermal synergy to achieve an improved organism deactivation rate substantially at a surface of a packaging material;



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FIG. 8A is a graph showing results of a demonstration test of the pulsed light treatment system of FIG. 8 using *Bacillus Subtillis* spores treated with heat and one flash of intense, short duration, broad spectrum polychromatic light; and

FIG. 9 is a schematic diagram of a pulsed light treatment system employing modified atmosphere packaging synergy to achieve an improved organism deactivation rate substantially at a surface of the food product, as well as increased merchantability of the food product.

Corresponding reference characters indicate corresponding components throughout the several views of the drawings.

#### Detailed Description of the Invention

The following description of the presently contemplated best mode of practicing the invention is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the claims.

Referring first to FIG. 1, a schematic diagram is shown of a pulsed light treatment system 10 employing chemical agent synergy to achieve an improved organism deactivation rate substantially at (i.e., within one millimeter of) a surface 12 of a food product 14. The pulsed light treatment system 10 may be used to treat, i.e., deactivate organisms on, numerous types of food products including meats, produce, and prepared foods. Furthermore, the pulsed light treatment system 10 is effective in deactivating numerous type of organisms including *Escherichia coli* and *Salmonella typhimurium*.

In operation, for example, a meat product, such as steak, is passed, using e.g., a conveyor belt (not shown), into a chemical spray zone of a chemical agent applicator 16, such as a sprayer. The chemical agent

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applicator 16 includes, by way of example, two spray nozzles 18, 20 and a chemical agent reservoir. When the food product 14 passes into the chemical agent applicator 22, a chemical agent 24 is released from the chemical agent reservoir 22 by opening a valve (not shown). In response to the opening of the valve, the chemical agent flows to the nozzles 18, 20 and is sprayed onto the surface 12 of the food product 14.

Note that various other methods for applying the chemical agent, other than spraying, can be employed in addition to or instead of the sprayer. For example, the food product 14 (or, as described below, packaging material) may be dipped into a reservoir, or bath, of the chemical agent 24; the chemical agent 24 can be brushed onto the surface of the food product 14 (or packaging material); the chemical agent 24 may be rolled onto the food product 14 (or packaging material) using rollers; the food product (or packaging material) may be fogged with a aerated mist of the chemical agent 24; or the chemical agent 24 may be applied using any other suitable method for applying a liquid or gas to a solid. In a further variation, the chemical agent 24 may be in gaseous form and may be applied to the food product (or packaging material) using a gas jet or the like. The chemical agent 24 is applied to the food product 14 by the applicator until it substantially covers the outer surface 12 of the food product 14. Excess chemical 24 agent may optionally be removed from the outer surface 12 before the food product 14 is passed out of the applicator.

In practice, the chemical agent may include acids (inorganic or organic, such as acetic, lactic or citric acids), bases (inorganic or organic, such as alkaline aqueous solutions of sodium hydroxide or trisodium phosphate), detergents and other surfactants and surface active agents, natural byproducts or

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synthetic molecules with biological activity (such as antibiotics, bacteriocins, nicin, antibodies, chitin etc.), and/or enzymes (such as proteases, lysozymes, etc. or other enzymes with biological or antimicrobial activity). In addition, numerous other chemical agents that increase deactivation of organisms when combined with pulsed light treatment can be used. Alternatively, the chemical agent may consist of hot or warm water having a temperature of at least 20 °C, e.g., 70 °C.

As described more completely below, note that when hot or warm water is utilized as the chemical agent, both chemical synergy and thermal synergy, described hereinbelow, operate to improve the deactivation rate of organisms substantially at (i.e., within one millimeter of) the surface of the food product 14.

In one embodiment of the pulsed light treatment system 10 (as shown in FIG. 1), after application of the chemical agent 24 (and possibly heat, in the event hot or warm water is used as the chemical agent), the food product 14 is passed from the applicator 16 into a pulsed light treatment zone, wherein the food product 14 is exposed to intense (i.e., 0.01 to 50 J/cm<sup>2</sup>, e.g., 0.5 J/cm<sup>2</sup>, energy density measured at the surface of the food product), short duration (i.e., from 0.001 to 100 milliseconds, e.g., 0.3 milliseconds) pulses of polychromatic light 28 in a broad spectrum (i.e., 170 to 2600 nm;  $1.8 \times 10^{15}$  Hz to  $1.2 \times 10^{14}$  Hz). For example, the food product 14 can be exposed to four pulses (or flashes) of the polychromatic light.

In practice, the intense, short duration pulses of broad spectrum polychromatic light 28 are generated using a flashlamp system 30, such as PUREBRIGHT Model No. PL-320 available from FoodCo Corp. of San Diego, California. The flashlamp system 30 includes a pulsing device (not shown) that includes a DC power supply that charges energy storage capacitors; a switch used to

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discharge the capacitors; a trigger circuit used to fire the switch at pre-programmed time intervals, in response to sensors that detect the position of the food product to be treated, or in response to a button being  
5 depressed; and a set of high voltage coaxial cables carrying the discharge pulses from a capacitor-switch assembly to a flashlamp assembly 26. The flashlamp assembly 26 includes from one to six flashlamps 32 mounted in metal reflectors 30 so as to direct the  
10 polychromatic light 28 emitted from the flashlamps 32 toward the food product 14.

One alternative system (not shown) utilizes a monochromatic light source, e.g., laser sources, that either pulses or continuously generates monochromatic  
15 light.

As a further alternative, the polychromatic lamp or the monochromatic source (that generates either coherent or incoherent monochromatic light) may be used to apply the polychromatic light, or the monochromatic  
20 light, respectively, for extended periods of time, i.e., for periods lasting more than one second, e.g., ten seconds or several minutes. The light of this alternative may be the broad spectrum polychromatic light of the preferred embodiment, or may be a narrower band of  
25 polychromatic light within the broad spectrum (170 nm to 2600 nm) defined above.

Thus, the light may also include continuous wave and monochromatic or polychromatic light having wavelengths outside the broad spectrum. However, at least  
30 60%, preferably at least 70%, of the energy of the light should be from light having wavelengths within the broad spectrum defined above.

The pulses of polychromatic light are preferably from between 0.001 ms to 100 ms, e.g., 0.3 ms,  
35 in duration and have a pulse repetition rate of from one to 100 pulses, e.g., 10 pulses, per second (Hz). The food

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product 14 can be exposed to, e.g., four pulses (or flashes) of the polychromatic light 28.

In one alternative variation, the intense, short duration, pulses of broad spectrum, polychromatic light may be applied to the surface of the food product prior to application of the chemical agent thereto. Such can be achieved using an apparatus similar to the pulsed light treatment system shown in FIG. 1 with the chemical agent applicator 16 and flashlamp assembly 26 being in reversed positions.

In another alternative variation, the food product 14 is not passed to a treatment zone separate from the chemical spray zone. Instead, the chemical spray zone and the pulsed light treatment zone are combined. In operation, the pulsed light treatment system of this alternative variation first applies the chemical agent 24, and then applies the intense, short duration pulses of broad spectrum polychromatic light 28, or vice versa.

Illumination of the entire surface of the food product is preferred and can be achieved by rotating (e.g., using rollers or a shaker apparatus) the food product 14 between two or more flashes of a polychromatic lamp 32; by dropping the food product 14 within the treatment zone and exposing the food product 14 from all sides as it falls; by moving the food product 14 through the treatment zone on a transparent carrier, e.g., a transparent conveyor belt; or by manually (hand) rotating the food product in the treatment zone.

The pulses of light 28 impinge upon the surface 12 of the food product 14, so as to deactivate organisms at or near (i.e., within one millimeter of) the surface 12 of the food product 14. Such exposure, in combination with the application of the chemical agent 24 (and possibly heat), deactivates, i.e., kills or sterilizes, a substantial portion (i.e., more than 50%, e.g., 90%) of the organisms on the surface 12 of the food product 14.

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In this way, improved deactivation of organisms substantially at the surface of the food product, i.e., an improved deactivation rate, is achieved.

Demonstration of the above-described chemical synergy is made by inoculating the surface of a beef carcass with 100 microliters *Escherichia coli* inoculum distributed as approximately ten small droplets across an 8 cm by 8 cm square area of the surface of the carcass. The inoculum is spread over the area using a bent glass rod and the organisms are allowed to attach for 30 minutes. Next, the area is sprayed for fifteen seconds using a 0.4 gallon per minute spray nozzle at 20 psi with a chemical agent consisting of 1.75% acetic acid in water. After a thirty second delay, the surface is treated with two flashes of broad spectrum, polychromatic light having a 0.3 mS pulse duration, a 1 pulse per second (Hz) repetition rate, and an energy density of 0.5 J/cm<sup>2</sup> measured at the surface of the carcass.

The area is next stomached (using a stomacher, which is a common laboratory device employing two paddles that pummel a sample within a bag containing a buffer, e.g., 100 ml of 0.1% peptone water, simulating processes carried out by a human stomach). The buffer is sampled and plated onto standard plate count agar (SPCA) plates and McConkey agar with Sorbitol (used as a selective and differential medium) (McC+S) plates. Standard microbiological techniques are then used to determine the logs of organisms still surviving. This quantity is compared to the logs of organisms measured on a control sample to determine the difference in logs of organisms, i.e., the increase in deactivation achieved by the combination of pulsed light treatment and the chemical agent. Results from an exemplary demonstration (including control samples and chemical-agent-only samples) are shown graphically in FIG. 1A.

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Referring to FIG. 1A, a graphical representation is shown of exemplary test results for the above demonstration. Organism levels are shown along a vertical axis (in logs CFU/cm<sup>2</sup>) for three sets of test data. The first set is a control group (representing areas of the carcass that are inoculated with *Escherichia coli*, but not treated), the second is inoculated and treated only with acetic acid and the third (described above) is inoculated and treated with acetic acid and intense, short duration pulses of broad spectrum, polychromatic light. Each of the sets contains five samples plated on SPCA and five samples plated on McC+S agar (represented as closed and open triangles, respectively). Within each of the three groups, an average organism level is represented for SPCA and McC+S agar (as a closed and as an open square, respectively). Two additional control samples are taken on areas of the carcass that are not inoculated with *Escherichia coli* (referred to in FIG. 1A as "uninoculated controls"). Organism counts for such uninoculated control samples are plated on SPCA and McC+S agar (represented by closed and open triangles, respectively), and average organism counts are represented (by closed and open squares for SPCA and McC+S agar, respectively).

A similar demonstration of chemical synergy may also be performed using three, as opposed to two, intense, short duration pulses of broad spectrum polychromatic light. Results from such a demonstration are shown graphically in FIG. 1B. Test data for three groups of samples is represented in FIG. 1B in a manner similar to such representations in FIG. 1A.

Results from a demonstration using *Salmonella typhimurium* instead of *Escherichia coli*, and using three intense, short duration pulses of broad spectrum polychromatic light area shown graphically in FIG. 1C. Test data for three groups of samples is represented in

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FIG. 1C in a manner similar to such representations in FIG. 1A. Instead of McC+S agar and SPCA agar, brilliant green (BG) agar and SPCA agar are used in the Salmonella typhimurium demonstration.

5 Referring to FIG. 2, a schematic diagram is shown of a pulsed light treatment system 34 employing chemical agent synergy to achieve an improved organism deactivation rate substantially at a surface of a packaging material 35. A roll 36 of packaging material  
10 35, such as a laminate having an inner polyethylene layer, an aluminum foil layer, a paper layer, and an outer polyethylene layer, is shown. In practice, the packaging material 35 is passed through rollers 37 (or other appropriate mechanical guides) to a chemical agent  
15 spray zone, similar to that described above, wherein the chemical agent 24 is sprayed onto inner and outer surfaces of the packaging material 35 (or only one of the inner and outer surfaces, if desired). The packaging material 35 is then passed through additional rollers 37  
20 (or mechanical guides) to a pulsed light treatment zone, wherein intense, short duration, broad spectrum, polychromatic light pulses 28 (described above) are applied to one or both surfaces of the packaging material 35.

25 It is important that the light pulses 28 be of high intensity, however the light pulses 28 should not be of such intensity that they cause the inner or outer surface of the packaging material 35, i.e., the inner or outer layer of polyethylene, to melt, burn or ablate from  
30 the foil or paper layers.

After application of the pulses of light 28, the packaging material 35 is passed through a final set of rollers 37 (or mechanical guides) and to a conventional food packaging apparatus (not shown). In  
35 passing the packaging material 35, having been treated, to the packaging apparatus, it is important that the



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surfaces of the packaging material 35 (i.e., the treated surfaces) remain sterile so as to prevent reinfestation of the surfaces with organisms. Such packaging apparatuses are well known in the art of food processing and could easily be adapted by one skilled in the art to function with the apparatus of FIG. 2.

One example of such a food packaging apparatus adapted for use with the apparatus of FIG. 2 is shown in FIG. 3 wherein a detailed perspective view is shown of a first type of aseptic packaging apparatus 37. A roll or reel of packaging material 102 is directed by means of a series of rollers 104 through a reservoir 106 (i.e., through a dipping-trough) of the chemical agent. The packaging material 102 may typically comprise a layered structure of one or more internal coating and sealing layers (of, e.g., polyethylene), a metal foil (such as aluminum foil), a laminating layer (or paper layer) and an external layer (of, e.g., polyethylene), in accordance with conventional practice.

Excess chemical agent solution may be removed by rollers 110 or other such means, e.g., an air knife, and the packaging material may be subsequently formed into a longitudinally sealed tube by a longitudinal sealing apparatus 112. In the event a lap seal (as opposed to a fin seal) is desired, a strip 108 may be applied to one edge of the packaging material to reinforce the longitudinal seam, and to prevent the product from coming into contact with the edge of the packaging material 102. Application of such strips is known in the art.

An important aspect of the aseptic packaging apparatus 37 is a pulsed light filling and sterilization assembly 200 (or product filling and flashlamp assembly), shown in more detail in FIG. 4. The illustrated assembly 200 comprises an outer support tube 202, having attached thereto one or more flashlamps 204 distributed about and

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along the tube 202 such that upon pulsing, the entire inner surface of the longitudinally sealed tube of packaging material is subjected to a series (e.g., four) of intense (i.e., 0.01 to 50 J/cm<sup>2</sup>, e.g., 0.5 J/cm<sup>2</sup>,  
5 energy density measured at the surface of the packaging material), short duration (i.e., from 0.001 to 100 milliseconds, e.g., 0.3 milliseconds), broad-spectrum (e.g., 170 to 2600 nm;  $1.8 \times 10^{15}$  Hz to  $1.2 \times 10^{14}$  Hz) incoherent pulses of light.

10 Note that the light may also include continuous wave and monochromatic or polychromatic light having wavelengths outside the broad spectrum. However, at least 60%, preferably at least 70%, of the energy of the light should be from light having wavelengths within the broad  
15 spectrum defined above.

The light impinges upon the inner surface of the longitudinally sealed tube of packaging material, as to deactivate organisms substantially at (i.e., within one millimeter of) the surface of the packaging material.  
20 Such exposure, in combination with the chemical agent, deactivates, i.e., kills or sterilizes, substantially all (i.e., more than 50%, e.g., 90%) of the organisms on the surface of the packaging material.

A variety of arrangements of the flashlamps  
25 along the support tube 202 are contemplated, the essential feature being that the entire inner surface of the longitudinally sealed tube of packaging material is exposed to the pulsed light.

Within the support tube 202 is a sterile food  
30 product tube 206. Sterile food product 212 is fed into the longitudinally sealed tube of packaging material via the sterile food product tube 206. The sterile food product 212 can be produced by a variety of known techniques, including the use of light pulses as  
35 described in the '559 patent, or may be produced using a combination of intense incoherent light pulses, and

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preheating and/or treatment with a chemical agent (which may or may not be the same chemical agent as is used to treat the packaging material), as described herein. A flashlamp electrical cable 208 and optional lamp coolant lines 210 may be located intermediate the support tube 202, and the sterile food product tube 206. In addition, sterile air provided under pressure from a suitable supply (not shown) may be conducted for discharge within the longitudinally sealed tube of packaging material.

10 Sterile air may be produced by a variety of techniques, e.g., filtration or incineration, including the use of intense incoherent light pulses as described in the '559 patent.

In operation, after the longitudinally sealed tube of packaging material, which is transversely sealed by a suitable transverse sealing apparatus 114, has received a predetermined portion of sterile food product 212, the longitudinally sealed tube of packaging material is advanced one "package length", while the flashlamp assembly is pulsed a plurality of times in order to repeatedly sterilize, i.e., deactivate organisms on, the entire adjacent interior of the longitudinally sealed tube of packaging material above the sterile food product 212. Sterile air 220 exits the support tube 202 and is carried over the flashlamp assemblies to cool the flashlamps, to remove from the longitudinally sealed packaging material tube any ablation products produced by the flashlamp discharge and to prevent contamination from settling on the treated area. Following transverse

30 sealing, the packages may be separated into individual consumer packages 116.

The present method may also be applied to other types of aseptic packaging systems, such as those which utilize preformed produce containers. In this regard,

35 illustrated in FIG. 5 is an aseptic packaging apparatus 38. The packaging apparatus 38 utilizes preformed

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produce containers 302 which are introduced into a sterilization zone 304 of the packaging apparatus 38. The chemical agent, as previously described, may be sprayed into containers 302 by means of spraying apparatus 306. Subsequently, the containers 302 pass through a series of flashlamp treatment stations 308 in which reciprocating "U" shaped flashlamps, linear flashlamps, bulb type flashlamps and/or flashlamps of other configurations are introduced above or into the container openings and pulsed at least once per container 302. The series of treatment stations is then withdrawn and the containers are advanced by one station, as the process is repeated so that the entire interior surface of each of the containers is subjected to a plurality of intense incoherent light pulses as it progresses along the series of treatment stations 308. A sterile air purge apparatus may be utilized to remove any material ablated from the interior of the containers, to prevent contamination from settling in the treated containers, and to cool the flashlamps. A stationary battery of flashlamps may also be provided to treat the exterior and edge surfaces of the containers upon their passage through the flashlamp treatment zone. The containers, having been sterilized, subsequently pass through a filing station 312 where a food product is introduced into each of the containers, which are subsequently sealed at the top by a sterile lid.

A laminar flow of sterile air may be provided over the entire aseptic packaging apparatus 30 in order to prevent the infection of the containers. The sterile air may be provided by a gas sterilization apparatus 350 that includes an air input blower 352, which pumps air through a filter 354 to a pulsed light treatment zone 356 containing a bank of high power Xenon flashlamps 358 enclosed in a reflective housing 360. The sterile air is continuously forced through the treatment zone 356 at a

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rate that, in conjunction with the pulse rate of the lamps 358, insures that all of the sterile air is subjected to a plurality of high intensity polychromatic incoherent light pulses, as previously described, as it passes through the treatment zone 356. Desirably, the light pulses will be a UV-rich (i.e., having at least 5 percent of its light energy at wavelengths shorter than 300 nanometers) and will desirably have an energy density of at least 0.5 joule per square centimeter throughout the treatment zone through which all of the sterile air passes. The pulse duration may typically be in the range of from about 0.001 to 100 milliseconds, e.g., 0.3 milliseconds.

A multiple-lamp reflector array provides multidirectional, substantially even illumination to the air or other gas flowing therethrough, so that a dust particle or bacterial colony forming organism is treated from all sides and is not self-shielded.

Illustrated in FIG. 6 is an additional embodiment of an aseptic packaging apparatus 40 which comprises two rolls or reels 402, 404 of packaging material, one for the container body of the finished packages and one for package lids. The material for the container body is conducted through a reservoir 406 of the chemical agent, as previously described. The packaging material 402 for the container body is conducted through a suction and drier section to remove excess chemical agent, and is subsequently subjected to intense incoherent light pulses by an array 408 of flashlamps extending longitudinally along the direction of travel of the packaging material 402. After being subjected to the intense incoherent light pulses, the packaging material 402 is thermoformed into suitable containers by a forming apparatus 410. The containers are then filled with an aseptically processed food product or foodstuff at a filling station 412. The packaging

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material for the lid is also passed through a chemical agent bath 414, is subjected to a plurality of intense incoherent light pulses by a flashlamp array 416 and is utilized to seal the filled, formed containers. The entire apparatus is maintained under sterile air blanket similar to that described above.

Referring to FIG. 7, a schematic diagram is shown of a pulsed light treatment system 70 employing thermal synergy to achieve an improved organism deactivation rate substantially at a surface 12 of a food product 14. In practice, a food product 14, such as the food product 14 described in reference to FIG. 1, is passed through a heat treatment zone. A suitable conveyor (not shown), such as a conveyor belt, can be used to convey the food product 14.

Within the heat treatment zone, warm or hot water is used to spray the food product 14. The water is stored in a reservoir 702, from which it passes via a suitable conduit, such as a pipe. Heaters 704 heat the water within the reservoir (making it warm or hot water), and in response to the opening of a valve (not shown), the hot or warm water flows from the reservoir via a suitable conduit, such as a pipe, to one or more nozzles 700, 701. Such heaters 704 and reservoirs 702, e.g., water heaters, are well known in the art, and the nozzles 700, 701 can be any type of nozzle suitable for spraying the surface of the food product. The warm or hot water is heated to a temperature of at least 20 °C, e.g., to between 30 °C and 90 °C, preferably about 70 °C, by the heaters 704. As a result of the water being sprayed over the surface 12 of the food product 14, the surface 12 of the food product 14 is heated to approximately the temperature of the water. Such heating in, e.g., beef carcasses is evidenced by a whitening of the surface of the carcass. The natural color of the carcass does however return in the event the carcass is recooled.

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Note that in addition to heating the surface of the food product 14, the warm or hot water may interact chemically with organisms on the surface 12 of the food product 14. As a result, both thermal and chemical  
5 synergy may assist in the killing of organisms on the surface 12 of the food product 14 in this embodiment.

Note further that the temperature to which the food product 14 is preferably heated depends on the nature of the food product 14 and the type of organisms  
10 to be deactivated. Note, however, that the temperature to which the food product is heated need not be sufficient to deactivate organisms. For example, meats, such as beef carcasses, can be heated using warm or hot water that has a temperature of about 70 °C, which is  
15 insufficient to deactivate some types of organisms, and, advantageously, does not result in a changed flavor or changed coloration in the meat.

After being heated by the warm or hot water, the food product 14, is passed into a pulsed light  
20 treatment zone, wherein it is exposed to intense, short duration, broad spectrum, polychromatic light pulses 28, as described above. The light pulses 28, in combination with the heating of the food product, using warm or hot water or other heating means, such as ovens or heaters,  
25 cause an improved deactivation rate with respect to organisms at or near the surface of the food product 14.

Referring to FIG. 8, a schematic diagram is shown of a pulsed light treatment system 80 employing thermal synergy to achieve an improved organism  
30 deactivation rate substantially at a surface of (i.e., within 1 millimeter of) a packaging material 35. A roll or reel 36 of the packaging material 35 is shown. The packaging material 35 can be a laminated packaging material, as described above. In practice, the packaging  
35 material 35 is rolled off of the roll 36 through rollers 37 (or other mechanical guides) to a heat treatment zone,

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as described above. Within the heat treatment zone, heaters 800 are used to heat the packaging material 35 at its inner and/or outer surfaces (or either of the inner or outer surfaces, as described), and/or to heat the atmosphere, e.g., air, surrounding (or adjacent to) the packaging material 35. Preferably the packaging material 35 and/or atmosphere surrounding (or adjacent to) the packaging material 35 are heated to a temperature of at least 20 °C, e.g., 80 °C. Such heaters 800, which may be resistive heating elements, are well known in the art.

After being heated (and/or having the atmosphere around it heated) in the heat treatment zone, the packaging material 35 is passed through rollers 37 (or other mechanical guides) to a pulsed light treatment zone, as described above. Within the pulsed light treatment zone, lamps 32 are used to generate high intensity polychromatic light pulses 28, which are applied to the packaging material 35. The combination of the heating by the heaters 800 and the application of high intensity polychromatic light 28 by the lamps 32 results in an improved deactivation rate for organisms residing at or near the surface of the packaging material 35.

Note that the heat treatment zone and the pulse light treatment zone, may, in one embodiment, be combined in a single physical area. Within the single physical area, the heaters 800 may first increase the temperature of the packaging material 35 and/or atmosphere around the packaging material 35 and the flashlamps 32 may then apply the intense, short duration pulses of broad spectrum, polychromatic light 28.

The apparatus 80 shown in FIG. 8 is analogous to the apparatus 34 shown in FIG. 2, except that the apparatus 80 of FIG. 8 employs thermal synergy, as opposed to chemical synergy. Note however that the apparatuses 34, 80 of FIGS. 2 and 8 can easily be



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combined by passing the packaging material 35 through both the chemical spray zone and the heat treatment zone before the application of the pulsed light treatment.

(Such combination can also be made of the apparatuses in FIGS. 1 and 7 for treating the food product 14).

Depending on the application of the present invention, i.e., the organisms to be deactivated and the type of packaging material 35, the packaging material 35 can be first passed through the heat treatment zone or the chemical spray zone, and then passed through the other of these two zones before being passed through the pulsed light treatment zone. In addition, the chemical spray zone and/or the heat treatment zone may be combined with the pulsed light treatment zone in a single physical area.

Demonstration of thermal synergy is made placing a 10  $\mu$ l droplet containing  $7.1 \times 10^6$  spore colony forming units of *Bacillus pumilus* ATCC 27142 spores onto a surface of each of two polypropylene desert cups, such as those commonly used in the art of food packaging. The inoculum is allowed to dry (for about one hour). Next, one of the polypropylene desert cups is treated at about 20 °C with an intense, short duration pulse of broad spectrum polychromatic light. The intensity of the pulse of light is 2 J/cm<sup>2</sup> and its duration is 0.3 ms. The second of the polypropylene desert cups, and an air atmosphere surrounding the second desert cup are heated for about five minutes, using heaters (such as those shown in FIG. 8), to a temperature of about 60 °C. The second desert cup is then exposed to intense, short duration pulse of broad spectrum polychromatic light.

Each of the two polypropylene desert cups are next swabbed using a wet cotton swab (having been dipped in sterile water). Each wet swab is then placed into a test tube containing 3 ml of phosphate buffer, and broken off below the portion of the swab that has been handled.

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Next a dry swab is used to swab each of the polypropylene desert cups, and is also broken off into one of the test tubes. The test tubes are shaken to recover the spores from the swabs into the buffer. The buffer is sampled and  
5 plated onto standard plate count agar (SPCA) plates, and standard microbiological techniques are used to determine the logs of organisms still surviving. These quantities are compared to determine the difference in logs of organisms on the two desert cups, i.e., the increase in  
10 deactivation achieved by the combination of thermal treatment at 60 °C and the pulsed light treatment, over the deactivation achieved by the pulsed light treatment at 20 °C.

Additional demonstrations are carried out as  
15 described above using light pulses having intensities of 3 and 4 J/cm<sup>2</sup>. Results from exemplary demonstrations are shown graphically in FIG. 8A. Thus, it is shown that the application of heat in combination with the intense, short duration, broad spectrum, polychromatic light pulse  
20 results in increased deactivation of organisms residing at or near the surface of a packaging material.

Referring to FIG. 9, a schematic diagram is shown of a pulsed light treatment system 90 employing modified atmosphere packaging synergy to achieve an  
25 improved organism deactivation rate substantially at a surface 12 of the food product 14, as well as increased merchantability of the food product 14. In operation, the food product 14, such as beef steak, is passed through a packaging apparatus 900 wherein the food  
30 product is sealed in a modified atmosphere package 902. The packaging apparatus 900 can be any type of packaging apparatus that seals the food product 14 within a volume designed to contain a modified atmosphere. The modified atmosphere may be fully or partially evacuated, or  
35 pressurized; and/or may contain a chemical agent, such as a gas, liquid, liquid solution, gelatin, or the like. As

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an example, the modified atmosphere may include an elevated oxygen content, such as an oxygen content greater than atmospheric, i.e., greater than the concentration found in air, or such as a > 65% oxygen content.

After the food product 14 is sealed within the modified atmosphere package 902, it is passed into a pulsed light treatment zone wherein it is exposed to intense, short duration, broad spectrum, polychromatic light pulses 28. The light pulses 28 pass through the modified atmosphere package 902, which must allow light within a prescribed frequency range within the above-defined broad spectrum to pass through without excessive attenuation. Excessive attenuation occurs, for example if, in order to pass sufficient light energy through the modified atmosphere package 902 to effect deactivation of organisms at the surface of the food product, the polychromatic light impinging upon the surface of the modified atmosphere package 902 has to be of such great intensity that it causes the modified atmosphere package 902 to melt, burn or ablate.

As a result of the modified atmosphere package 902 being exposed to the pulses of light 28, organisms at or near the surface of the food product 14, i.e., within one millimeter of the surface of the food product 14, are deactivated. Furthermore, various other advantageous effects occur. For example, increased deactivation of organisms may occur when chemicals such as those described above are included in the modified atmosphere, or when a modified atmosphere evolves after the food product 14 is sealed within the modified atmosphere package 902. As a further example, in a preferred application wherein the food product is beef meat and the modified atmosphere package 902 contains higher concentrations of oxygen ( $O_2$ ) than atmospheric, e.g., > 65%  $O_2$  concentration, prolongation of the food product's

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red color is achieved. Because beef meat is prone to relatively quick discoloration when packaged using heretofore known techniques, this benefit is particularly advantageous. As a result of such prolongation of the  
5 beef meat's color, the food product 14 remains marketable for an extended period of time.

Note that the modified atmosphere package 902 need not contain a modified atmosphere at the time the food product 14 is sealed within the modified atmosphere  
10 package 902. Instead the modified atmosphere may evolve as a result of, e.g., chemical reactions that occur within the modified atmosphere package 902 after being sealed. The evolution of the modified atmosphere may or may not occur as a result of the food product 14 and/or  
15 modified atmosphere package 902 being exposed to the light pulses. The modified atmosphere, in some embodiments, can be characterized as a chemical treatment of the food product 14, and modified atmosphere packaging can, in such embodiments, be described as applying a  
20 chemical agent to the food product 14. Such is the case, for example, when one of the chemical agents described above are included in the modified atmosphere, or when chemical reactions occurring after the food product 14 is packaged, result in the modified atmosphere. Thus,  
25 modified atmosphere packaging synergy can, in some embodiments, be accurately described as a form of chemical synergy, which is described in reference to FIG. 1. As with the chemical synergy described in FIG. 1, modified atmosphere packaging, may advantageously be  
30 combined with thermal synergy to achieved an increased deactivation rate, and potentially prolongation of the period during which the food product remains merchantable.

While the invention herein disclosed has been  
35 described by means of specific embodiments and applications thereof, numerous modifications and

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variations could be made thereto by those skilled in the art without departing from the scope of the invention set forth in the claims.

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## CLAIMS

What is claimed is:

1. An improved method for preserving a perishable food product including:
  - 5 heating a surface of the food product to a prescribed temperature; and
  - illuminating the surface of the food product with light having frequencies within a prescribed frequency range, at least a portion of the light
  - 10 deactivating organisms substantially at the surface of the food product;
  - whereby improved preservation of the perishable food product is achieved.
- 15 2. The method of Claim 1 wherein said heating includes heating said surface of said food product to at least 30 °C.
3. The method of Claim 1 wherein said heating
- 20 includes heating said surface of said food product to at least 60 °C.
4. The method of Claim 1 including:
  - applying a chemical agent to said surface of
  - 25 said food product.
5. An improved system for preserving a perishable food product including:
  - heating means for heating a surface of the food
  - 30 product to a prescribed temperature; and
  - illuminating means for illuminating the surface of the food product with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface
  - 35 of the food product;

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whereby improved preservation of the perishable food product is achieved.

6. The method of Claim 5 wherein said heating means includes means for heating said surface of said food product to at least 30 °C.

7. An improved method for deactivating organisms substantially at a surface of a packaging material:

heating an atmosphere adjacent to the surface of the packaging material to a prescribed temperature; and

illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material;

whereby improved deactivation of organisms substantially at the surface of the packaging material is achieved.

8. The method of Claim 7 wherein said heating includes heating said atmosphere to at least 60 °C.

9. The method of Claim 8 wherein said heating includes heating said atmosphere to a temperature of at least 60 °C, said packaging material including polyethylene and said heating of said atmosphere being to a temperature less than a temperature at which the packaging material melts.

10. The method of Claim 8 wherein said heating includes heating said atmosphere to a temperature of at least 60 °C, said packaging material including polypropylene and said heating of said atmosphere being

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to a temperature less than a temperature at which the packaging material melts.

11. The method of Claim 7 including:  
5           applying a chemical agent to said surface of said food product.

12. An improved method for deactivating  
organisms substantially at a surface of a packaging  
10 material:  
          heating the surface of the packaging material to a prescribed temperature; and  
          illuminating the surface of the packaging material with light having frequencies within a  
15 prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material;  
          whereby improved deactivation of organisms substantially at the surface of the packaging material is  
20 achieved.

13. The method of Claim 12 wherein said heating includes heating said surface of said packaging material to at least 60 °C.

25  
14. The method of Claim 13 wherein said heating includes heating said surface of said packaging material to at temperature of at least 60 °C, said packaging material including polyethylene and said  
30 heating of said surface being to a temperature less than a temperature at which the packaging material melts.

15. The method of Claim 13 wherein said heating includes heating said surface of said packaging  
35 material to a temperature of at least 60 °C, said packaging material including polypropylene and said



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heating of said surface being to a temperature less than a temperature at which the packaging material melts.

16. The method of Claim 12 including:  
5       applying a chemical agent to said surface of said food product before said illuminating.

17. An improved system for deactivating organisms substantially at a surface of a packaging  
10 material:

heating means for heating an atmosphere adjacent to the surface of the packaging material to a prescribed temperature; and

15 illuminating means for illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material;

20 whereby improved deactivation of organisms substantially at the surface of the packaging material is achieved.

18. An improved system for deactivating organisms substantially at a surface of a packaging  
25 material:

heating means for heating the surface of the packaging material to a prescribed temperature;

30 illuminating means for illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material;

35 whereby improved deactivation of organisms substantially at the surface of the packaging material is achieved.

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19. An improved method for preserving a perishable food product including:

applying a chemical agent to a surface of the food product, the chemical agent including at least one  
5 chemical selected from a group of chemicals including an acid, a base, a surfactant, an enzyme, a natural byproduct and a synthetic molecule; and

illuminating the surface of the food product with light having frequencies within a prescribed  
10 frequency range, at least a portion of the light deactivating organisms substantially at the surface of the food product;

whereby improved preservation of the perishable food product is achieved.

15

20. The method of Claim 19 wherein said applying includes applying a solution of said chemical agent and water to said surface of said food product.

20

21. The method of Claim 19 including:  
heating a surface of said food product to a prescribed temperature.

22. An improved method for deactivating  
25 organisms substantially at a surface of a packaging material including:

applying a chemical agent to the surface of the packaging material, the chemical agent including at least one chemical selected from a group of chemicals including  
30 an acid, a base, a surfactant, an enzyme, a natural byproduct and a synthetic molecule; and

illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the  
35 light deactivating organisms substantially at the surface of the packaging material;

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whereby improved deactivation of organisms substantially at the surface of the packaging material is achieved.

5                   23. The method of Claim 22 wherein said applying includes applying a solution of said chemical agent and water to said surface of said packaging material.

10                   24. The method of Claim 22 including:  
                  heating a surface of said packaging material to a prescribed temperature.

                  25. An improved method for preserving a  
15 perishable food product including:  
                  applying a chemical agent to a surface of the food product, the chemical agent including a chemical other than water and other than an absorption enhancing agent; and

20                   illuminating the surface of the food product with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the food product;

25                   whereby improved preservation of the perishable food product is achieved.

                  26. The method of Claim 25 wherein said applying includes applying a solution of said chemical  
30 agent and water to said surface of said food product.

                  27. The method of Claim 25 including:  
                  heating a surface of said food product to a prescribed temperature.

35

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28. An improved method for deactivating organisms at a surface of a packaging material including: applying a chemical agent to the surface of the packaging material, the chemical agent including a chemical other than an absorption enhancing agent; and illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material; whereby improved deactivation of organisms substantially at the surface of the packaging material is achieved.

29. The method of Claim 28 wherein said applying includes applying a solution of said chemical agent and water to said surface of said packaging material.

30. The method of Claim 28 including: heating a surface of said packaging material to a prescribed temperature.

31. The method of Claim 28 including: heating an atmosphere adjacent to a surface of said packaging material to a prescribed temperature.

32. An improved system for preserving a perishable food product including: applicator means for applying a chemical agent to a surface of the food product, the chemical agent including a chemical other than water and other than an absorption enhancing agent; and illuminating means for illuminating the surface of the food product with light having frequencies within a prescribed frequency range, at least a portion of the

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light deactivating organisms substantially at the surface of the food product;

whereby improved preservation of the perishable food product is achieved.

5

33. An improved system for deactivating organisms at a surface of a food product including:

applicator means for applying a chemical agent to the surface of the packaging material, the chemical agent including a chemical other than an absorption enhancing agent;

illuminating means for illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material;

whereby improved deactivation of organisms substantially at the surface of the packaging material is achieved.

20

34. An improved method for preserving a perishable food product including:

heating water to a prescribed temperature;

applying the water, having been heated, to a surface of the food product; and

illuminating the surface of the food product with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the food product;

whereby improved preservation of the perishable food product is achieved.

35

35. The method of Claim 34 including:

heating said water to at least 30 °C.

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36. An improved method for deactivating organisms substantially at a surface of a packaging material including:

- heating water to a prescribed temperature;
- 5 applying the water, having been heated, to the surface of the packaging material; and
- illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the
- 10 light deactivating organisms substantially at the surface of the packaging material;

whereby improved deactivation of organisms at the surface of the packaging material is achieved.

- 15 37. An improved system for preserving a perishable food product including:

- heating means for heating water to a prescribed temperature;
- applying means for applying the water, having
- 20 been heated, to a surface of the food product; and
- illuminating means for illuminating the surface of the food product with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface
- 25 of the food product;

whereby improved preservation of the perishable food product is achieved.

- 30 38. An improved system for deactivating organisms substantially at a surface of a packaging material including:

- heating means for heating water to a prescribed temperature;
- applying means for applying the water, having
- 35 been heated, to the surface of the packaging material;
- and

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illuminating means for illuminating the surface of the packaging material with light having frequencies within a prescribed frequency range, at least a portion of the light deactivating organisms substantially at the surface of the packaging material;

whereby improved deactivation of organisms substantial at the surface of the packaging material is achieved.

39. An improved method for preserving a perishable food product including:

sealing the food product within a package designed to contain a modified atmosphere; and

illuminating the package with light having frequencies within a prescribed frequency range, at least a portion of the light passing through the package and deactivating microorganisms substantially at the surface of the food product;

whereby improved preservation of the perishable food product is achieved.

40. The method of Claim 39 wherein said sealing includes sealing said food product into said package, wherein said package contains a gas and said gas includes at least 65% oxygen.

41. The method of Claim 39 wherein said sealing includes sealing said food product into said package, wherein said package contains a chemical agent.

30

42. The method of Claim 39 including:  
heating said food product, having been sealed in said package, to a prescribed temperature.

43. An improved system for preserving a perishable food product including:

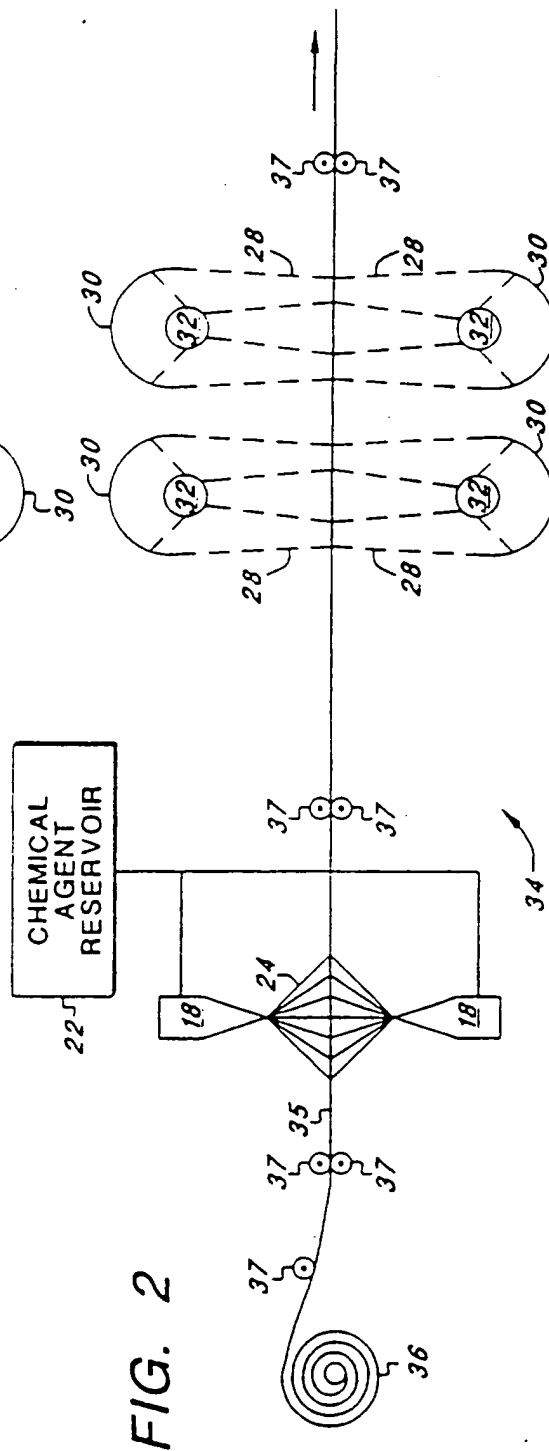
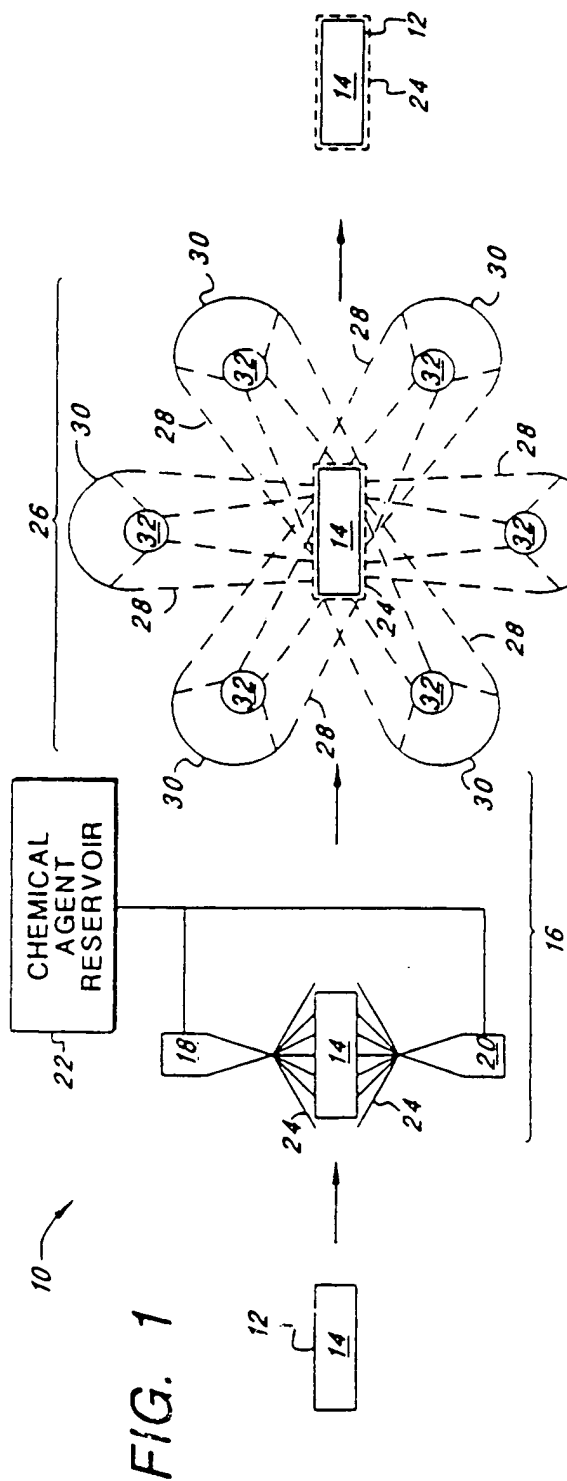
-38-

packaging means for sealing the food product within a package designed to contain a modified atmosphere; and

5 illuminating means for illuminating the package with light having frequencies within a prescribed frequency range, at least a portion of the light passing through the package and deactivating microorganisms substantially at the surface of the food product;

10 whereby improved preservation of the perishable food product is achieved.





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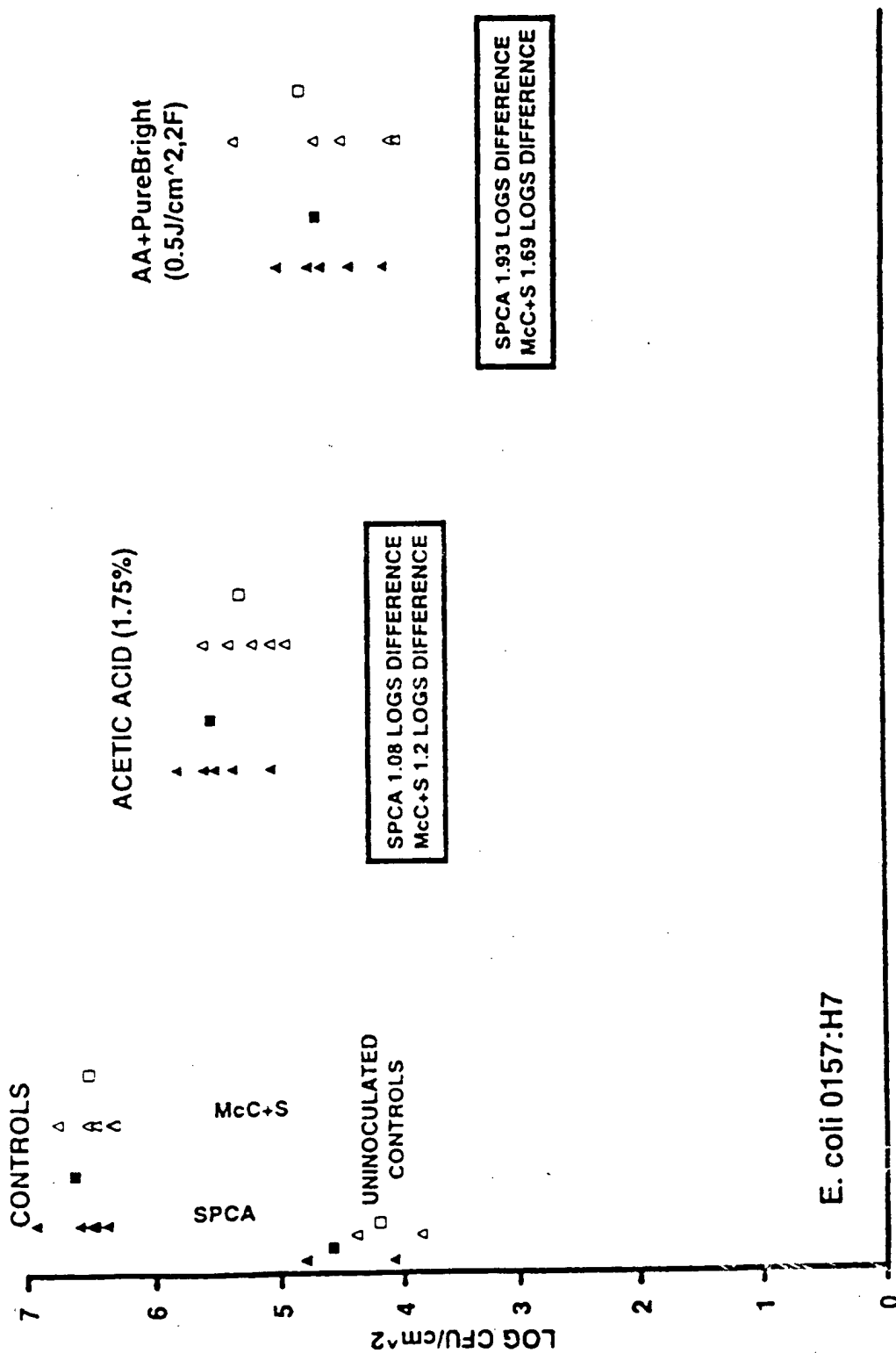


FIG. 1A

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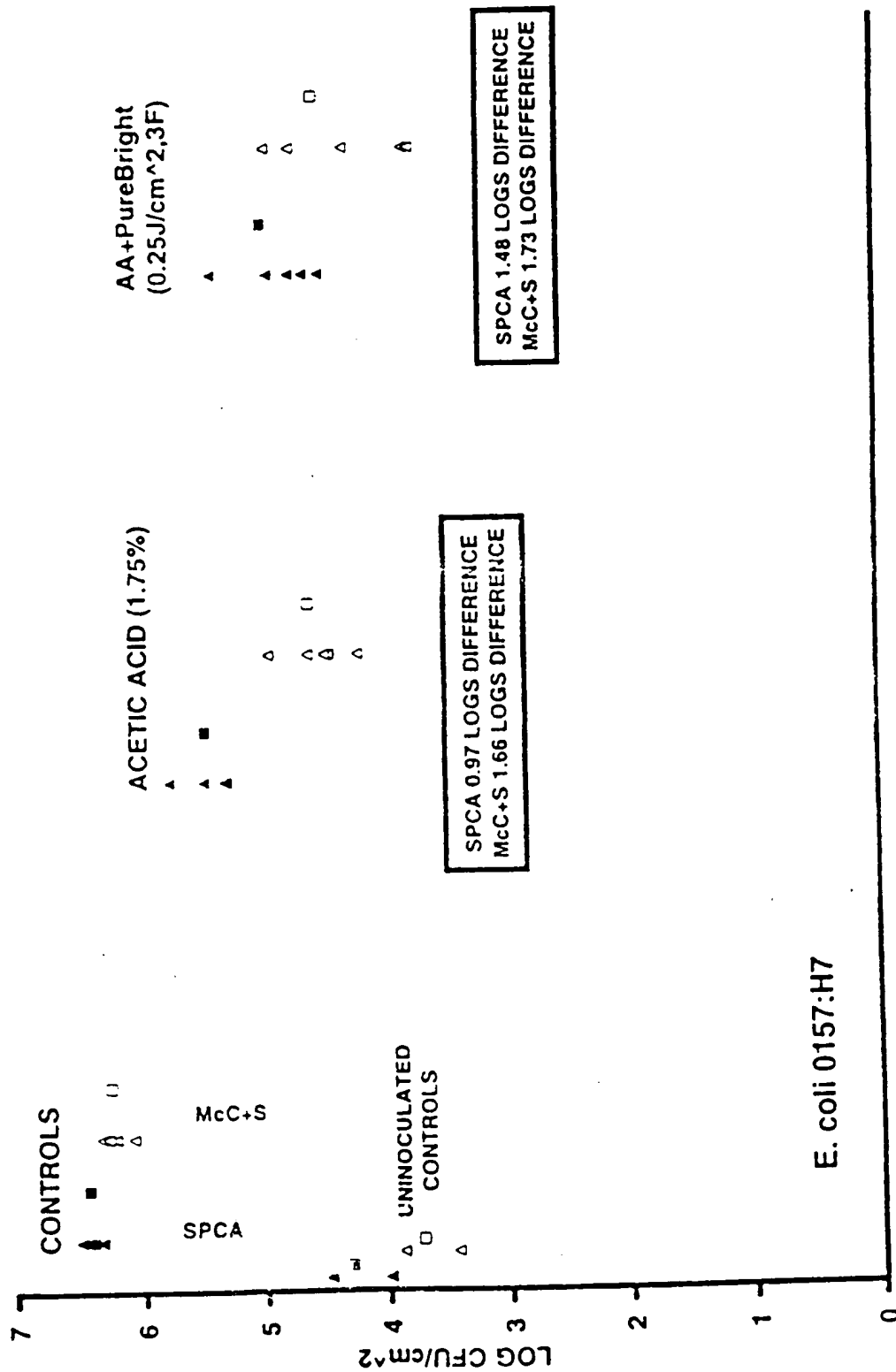


FIG. 1B

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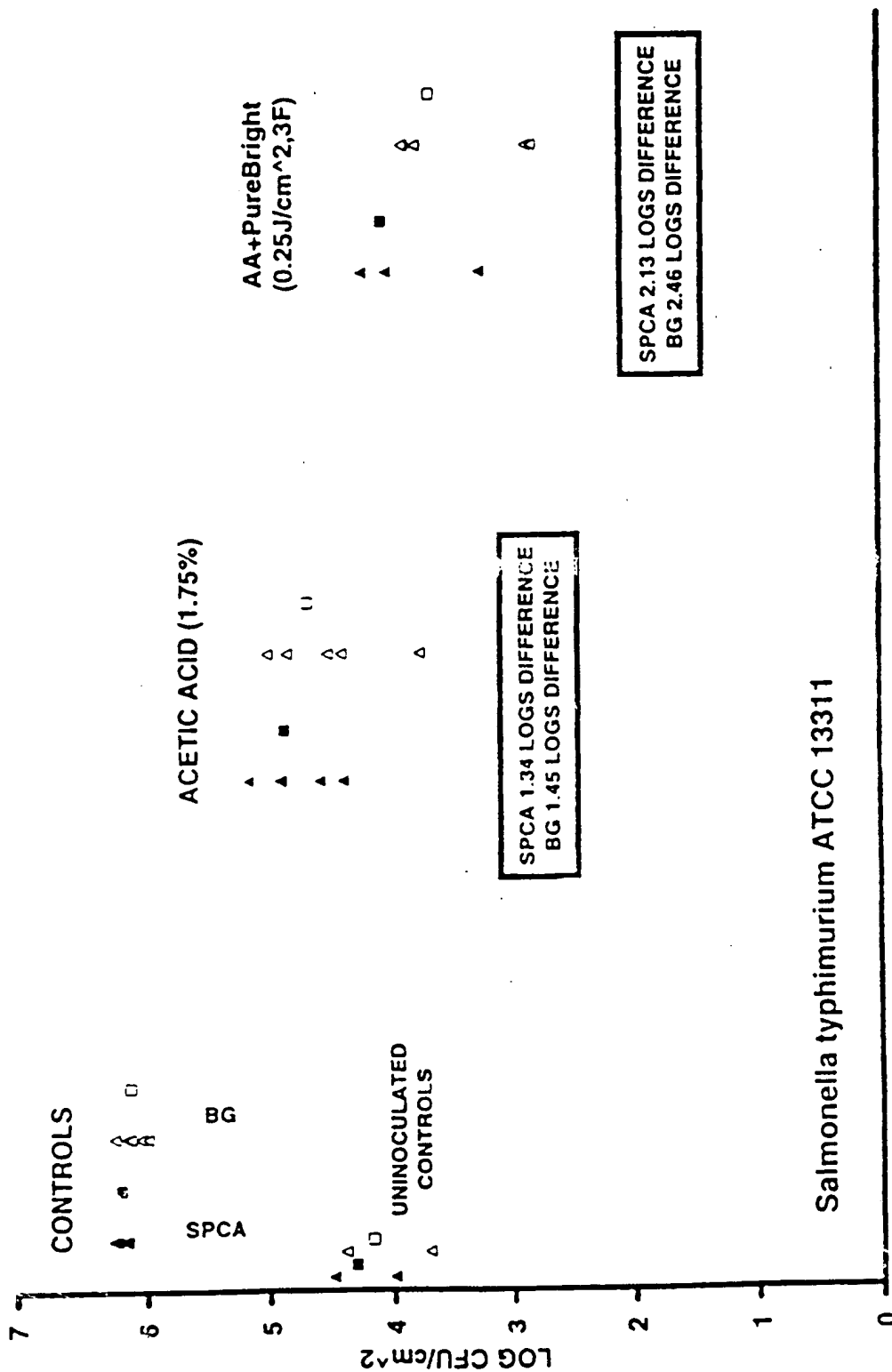


FIG. 1C

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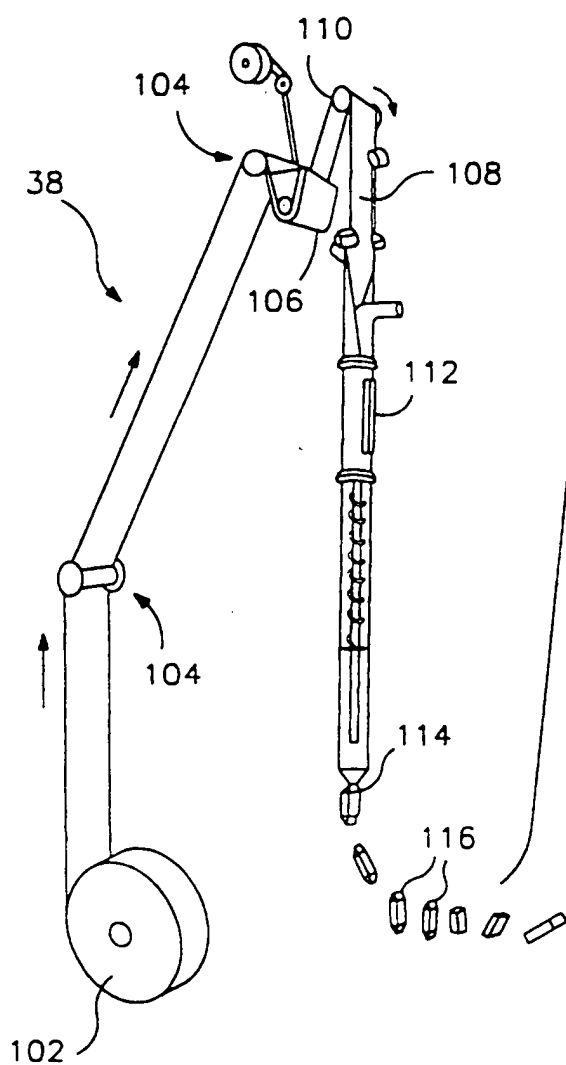


FIG. 3

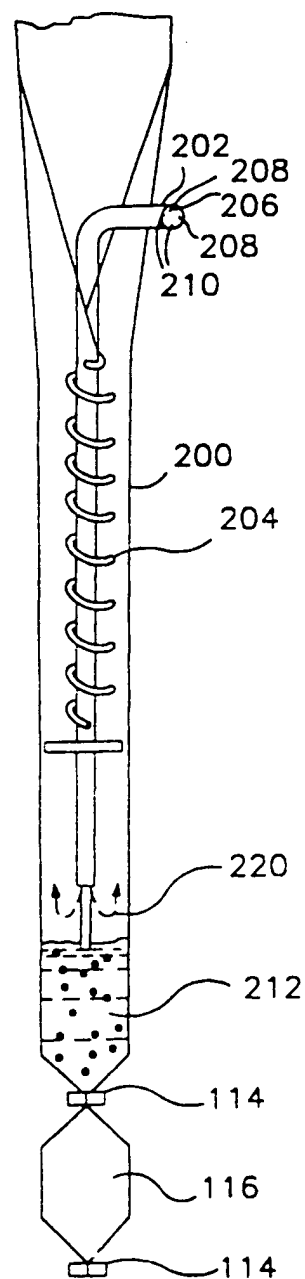


FIG. 4

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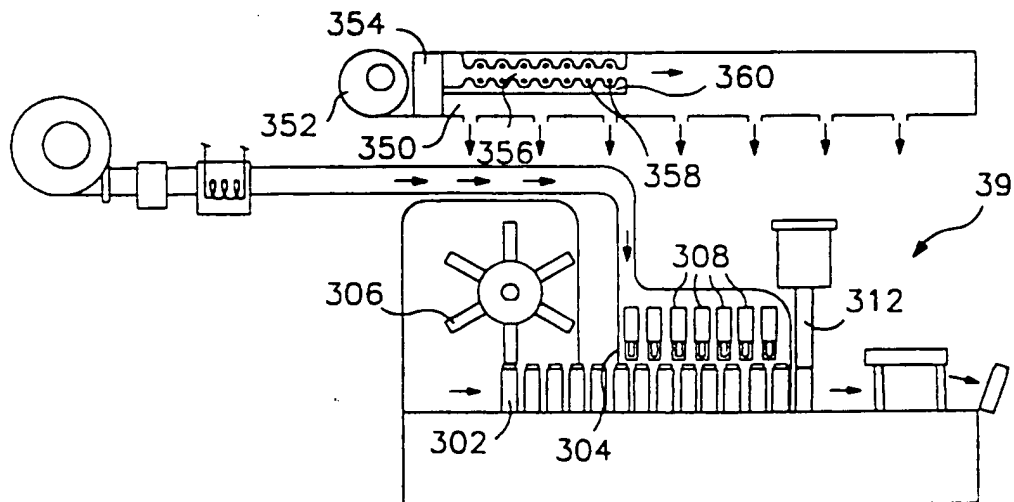


FIG. 5

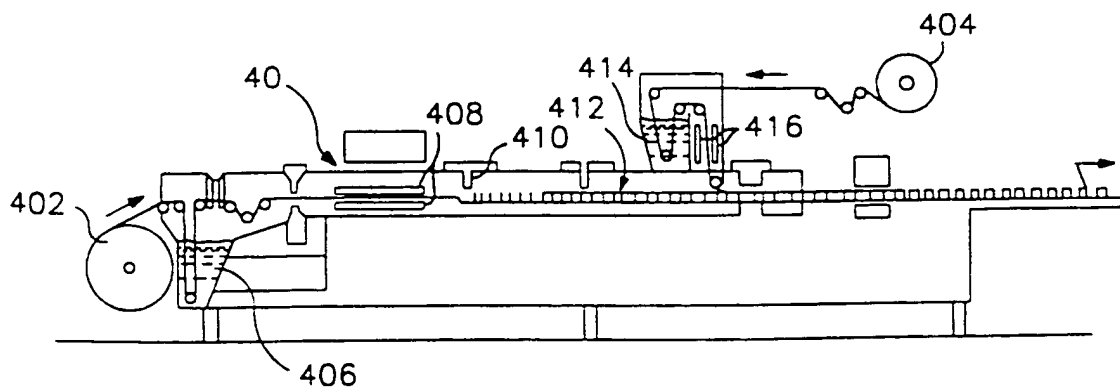
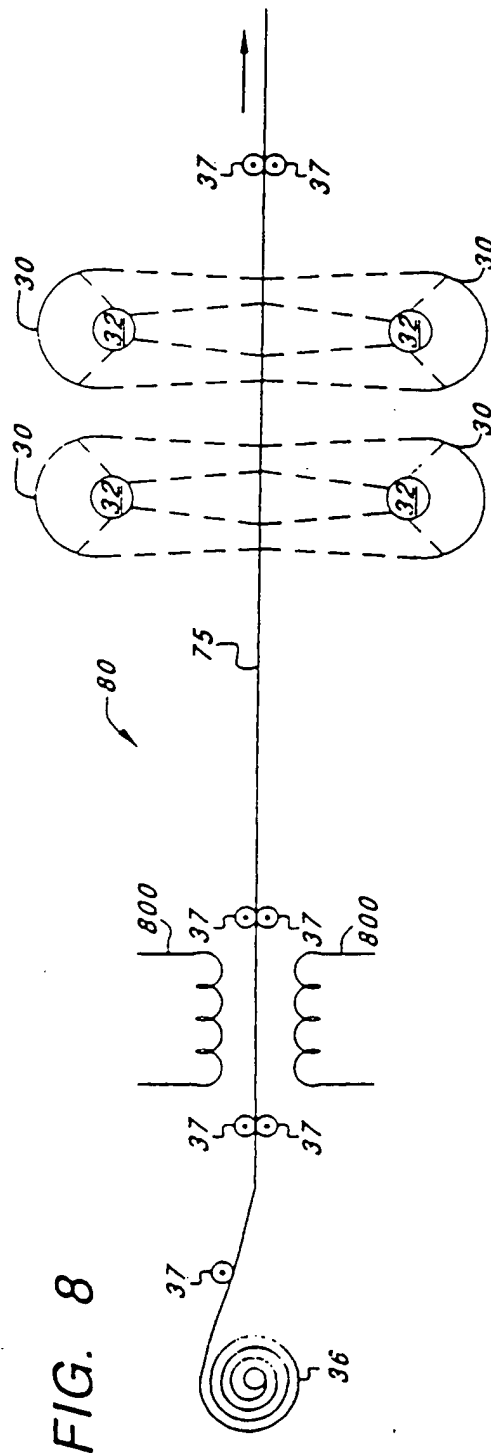
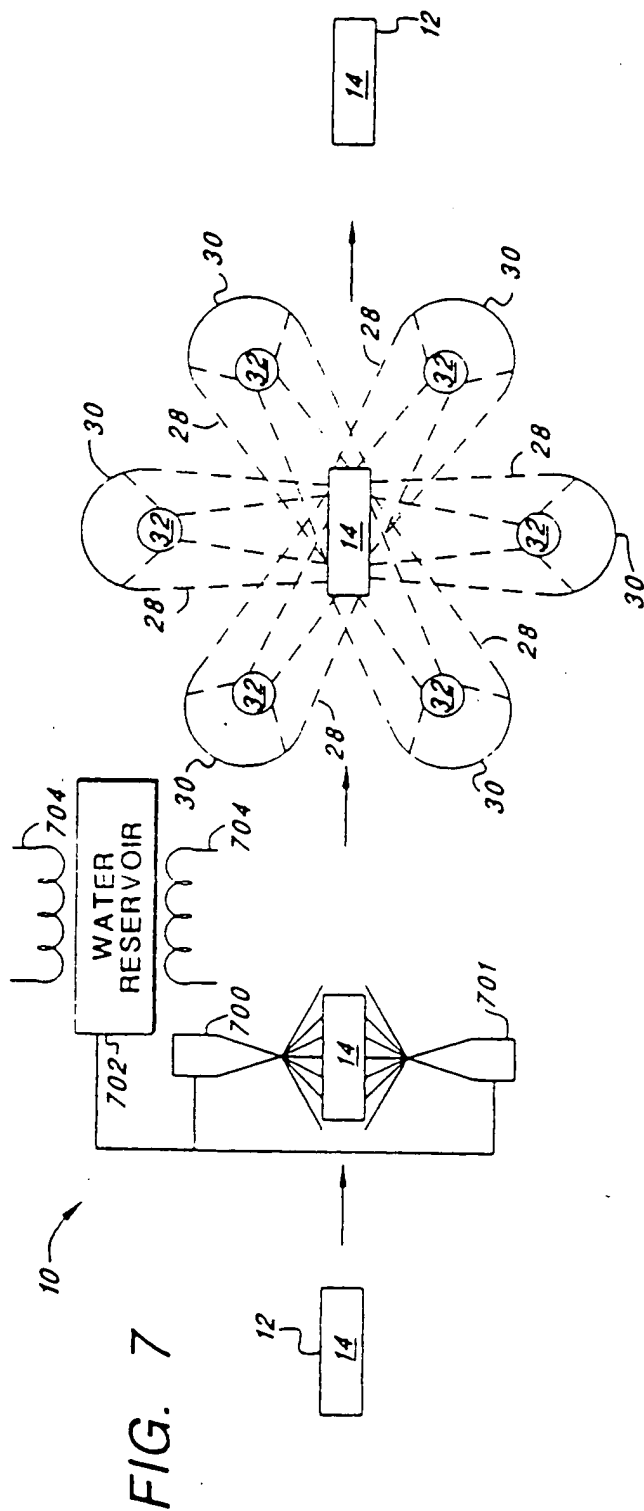


FIG. 6

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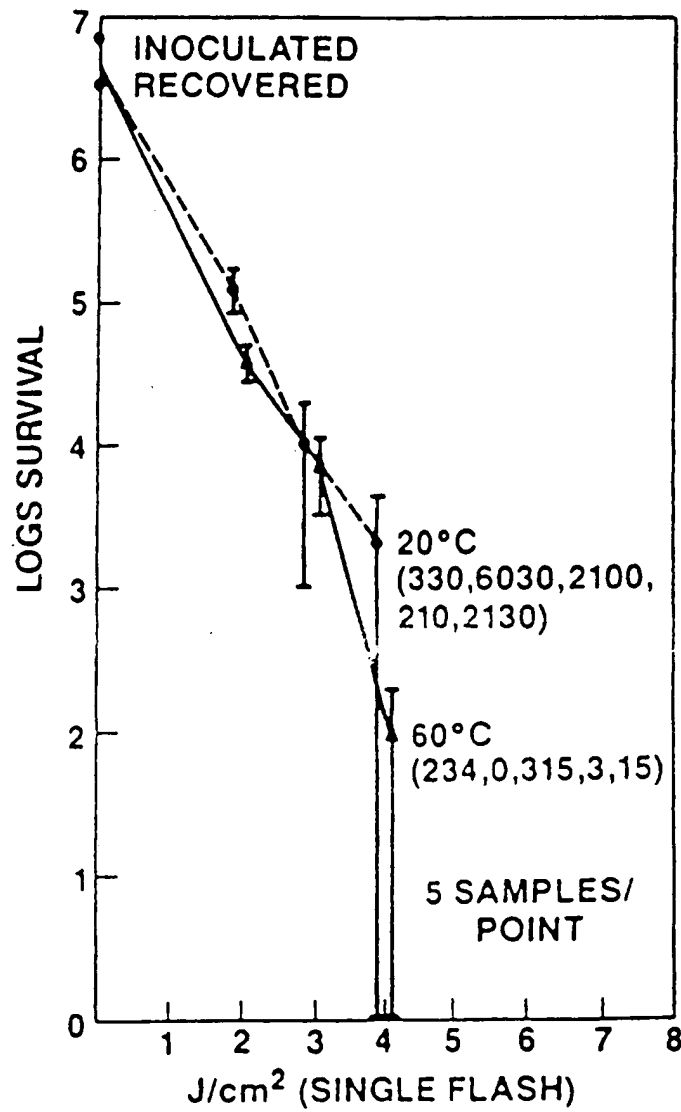
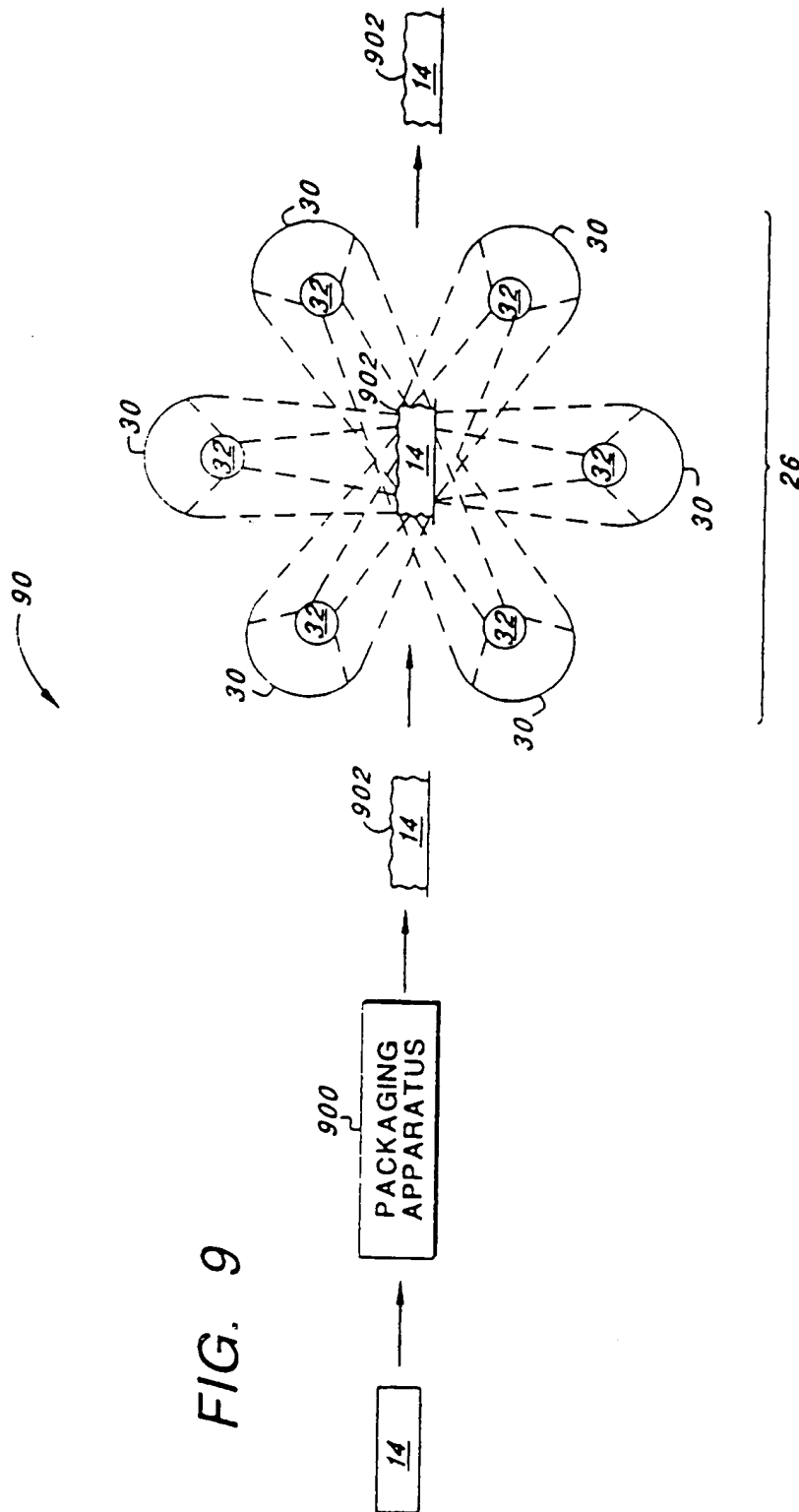


FIG. 8A



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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US95/10488

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : A23L 3/00; A61L 2/00; B65B 55/00

US CL : 426/248, 325, 326, 521; 53/167, 426; 422/24, 28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 426/248, 325, 326, 521; 53/141, 167, 426; 422/22, 24, 28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,871,559 (DUNN ET AL) 03 October 1989, see the entire document.	1-43
X	US, A, 4,396,582 (KODERA) 02 August 1983, see column 3, lines 58-64, column 6, lines 52-56, column 7, line 65 to column 8, line 16, and column 10, lines 6-10 and 53-58.	5-18, 22- 24, 28-33, 36-38
Y	US, A, 3,934,044 (BUSCH ET AL) 20 January 1976, see the entire document.	19-21, 25-27

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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